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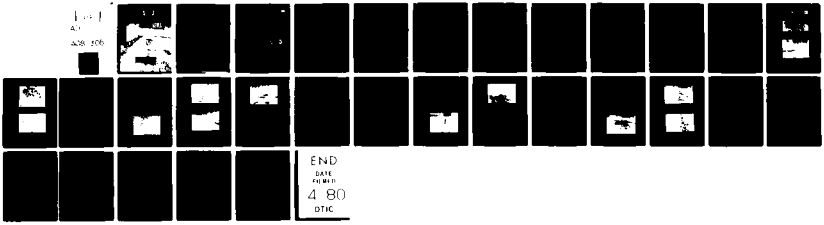

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Revegetation at two construction sites in New Hampshire and Alaska

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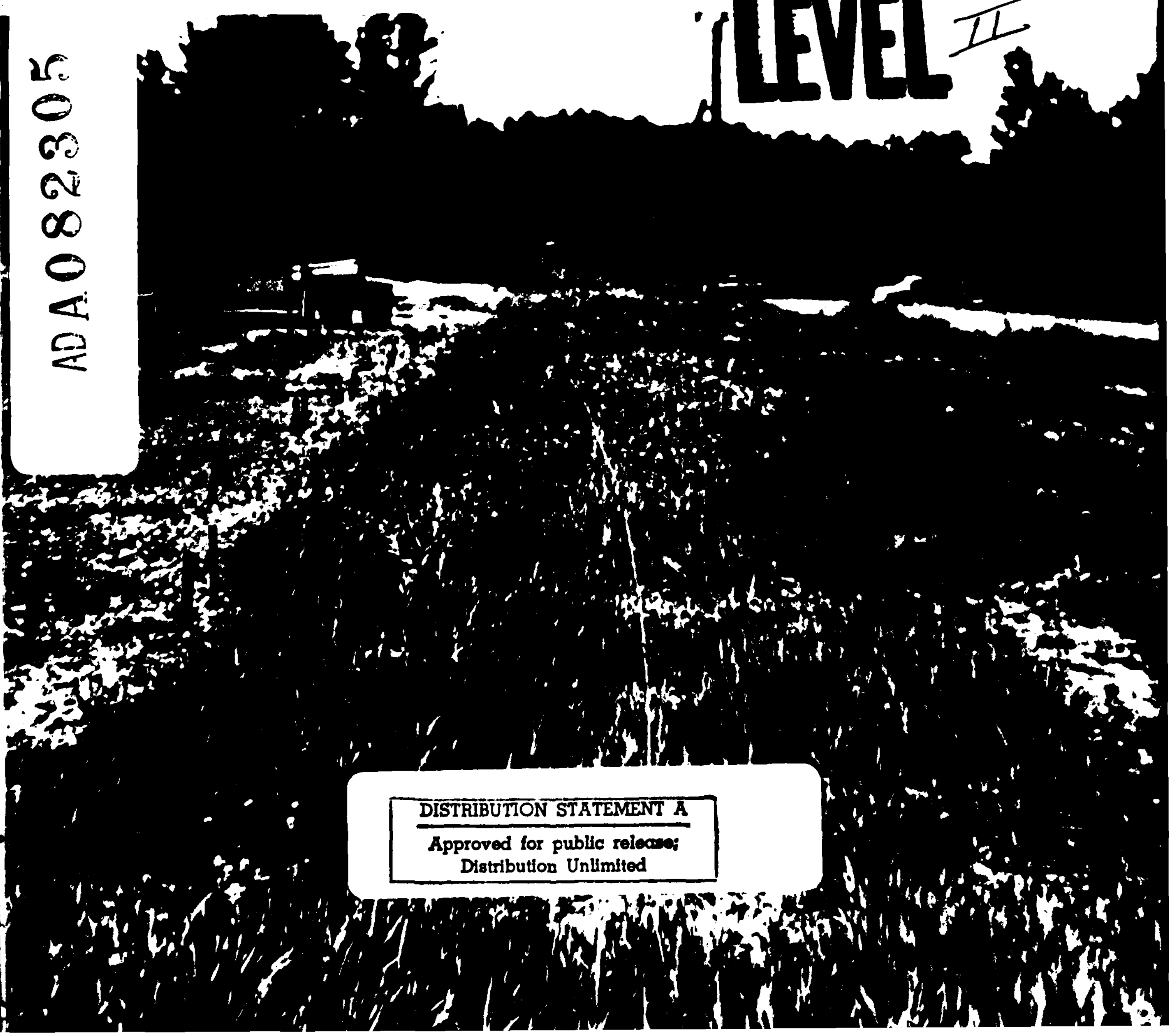

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Cover: *Field site in Hanover, New Hampshire. Darker colored grass at left is growing on plots that initially received sewage sludge and were subsequently refertilized during the second growing season. Grass at right is growing in soil that received only sewage sludge. (Photograph by A.J. Palazzo.)*

CRREL Report 80-3

Revegetation at two construction sites in New Hampshire and Alaska

A.J. Palazzo, S.D. Rindge and D.A. Gaskin

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Revegetation techniques were investigated for gravel soils in cold regions. Two gravel soil test sites were established in Hanover, New Hampshire, and Fairbanks, Alaska. During three growing seasons, we studied the applicability and cost effectiveness of various nutrient sources and mulch materials. The nutrient sources included sewage sludge (at 40, 60 and 80 tons/acre) and commercial fertilizer (at 200, 400 and 600 lb/acre). The mulching materials were wood fiber mulch with various types of tackifiers, peat moss, and sewage sludge. The effects of refertilization during the second growing season were also studied.

At both sites the use of sewage sludge produced superior results in many respects to the use of fertilizer at the

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application rates studied. Grasses receiving sludge showed better establishment rates and greater plant cover and growth, and were better able to withstand the hot drying conditions encountered during the summer months. Slightly quicker grass establishment was noted at the higher rates of application of each nutrient source in Fairbanks, while grass establishment at all sludge rates was good in Hanover. All fertilizer treatments performed poorly in Hanover. No evidence of winter injury to the grasses was noted in any of the treatments.

Supplemental applications of nitrogen fertilizer in Hanover during spring of the second growing season proved highly beneficial. The fertilizer helped maintain grass growth even during dry summer conditions.

The mulches were applied at the rate of 2,000 lb/acre. They were found to be important in providing a more nearly optimum environment for seedling establishment. Wood fiber mulch and the commercial Wood Fiber Mulch 2000, generally, were the best performers. Slower grass establishment was noted when peat moss was used. Applications of sewage sludge and fertilizer increased the general fertility of the soil, while lime applications increased soil pH. The increase in soil fertility and pH at the lower soil depths relates to the leaching of these materials throughout the soil profile. This leaching accounts for the loss of nutrients needed for plant growth and shows the importance of periodic soil testing.

A cost analysis was performed to determine the more cost effective treatments. Sewage sludge was found to be more expensive than fertilizer. The increased effectiveness of the sludge can justify its added expense, which was highly dependent on transportation. The two mulches that performed best, wood fiber mulch and Wood Fiber Mulch 2000, were among the least expensive mulches.

PREFACE

This report was prepared by Antonio J. Palazzo, Research Agronomist, Susan D. Rindge, Physical Scientist, and David A. Gaskin, Geologist, of the U.S. Army Cold Regions Research and Engineering Laboratory. The study was funded under DA Project 4A762720A896, *Environmental Quality for Military Facilities;* Technical Area B, *Source Reduction Control and Treatment;* Work Unit 025, *Revegetation of Terrain in Cold Regions.*

The authors wish to express their appreciation to Dr. F.H. Erbisch, Captain E.W. Price, L.A. Johnson and R. Bates for their technical review of the report. They also thank Wayne Hannel and Edward Gerard, Biologists, and John Graham and Nancy Robertson, Biology Technicians, for their technical assistance during the three-year study. Appreciation is also expressed to the U.S. Army Meteorological Team, Hanover, N.H., Detachment, for collecting meteorological support data.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

Multiply	*By*	*To obtain*
inch	25.4	millimeter
gallon	3.8	liter
pound	0.4536	kilogram
pound/acre	1.121	kilogram/hectare
ton/acre	2.240	megagram/hectare
dollar/acre	2.471	dollar/hectare
degrees Fahrenheit	$t_{°C} = (t_{°F} - 32)/1.8$	degrees Celsius

REVEGETATION AT TWO CONSTRUCTION SITES IN NEW HAMPSHIRE AND ALASKA

A.J. Palazzo, S.D. Rindge and D.A. Gaskin

INTRODUCTION

Soil stabilization after construction in cold regions presents some unique problems for revegetation practices, because of the shorter plant growing season and low winter temperatures in these regions. Construction operations may strip the thin layer of productive topsoil or the soil A horizon from the site and expose subsoils, such as gravels, that exist in the B or C horizon. Topsoils in cold and remote areas may be either unavailable or economically unfeasible to obtain for revegetation purposes. Thus, a seedbed results that may be low in pH, fertility, organic matter, and moisture holding capacity. To improve growing conditions on these soils, it is necessary to find readily available and cost effective materials to increase the nutrient content and water holding capacity of the soils.

The objectives of this study were to investigate the applicability and cost effectiveness of various nutrient sources and mulch materials for revegetating gravel soils in cold regions. Applicability is measured by the effectiveness of materials in helping to revegetate areas by either supplying plant nutrients, or maintaining soil moisture. The cost effectiveness of materials relates to their cost and availability versus their applicability.

LITERATURE REVIEW

Available information on revegetation practices for gravel soils in cold regions is limited. But related information is available on the growth of plants and use of fertilizers on exposed subsoils. Examples of research performed on exposed subsoils include studies on agricultural and strip-mined lands and on other work at CRREL regarding revegetation techniques after construction operations.

Interest in information on exposed subsoils in agricultural areas has arisen because of land forming operations which utilize this information to improve crop production. Olsen[21] noted reductions in corn yields when 12 to 14 in. of topsoil was removed. The addition of nitrogen, phosphorus, potassium and zinc has been recommended to promote plant growth on such subsoils[8,10,11,23,25]. Carlson et al.[8] reported that nitrogen was the most limiting element in the subsoil studied, followed by phosphorus and then zinc. The latter authors also reported that applications of these three elements and manure were necessary to obtain similar yields to those noted on surface soils[8]. Eck[10] and Eck et al.[11] reported that nitrogen and phosphorus and optimum soil moisture were required to obtain maximum yields of sorghum on an exposed subsoil. Babalola and Lal[2] noted that the growth of maize seedlings was adversely affected when soils contained a high concentration of gravels in subsoils. In a separate study[1], these authors noted a reduced rate of root elongation when the soil gravel content was greater than 10 to 20%.

The use of biologically treated sewage sludge as a soil amendment and as a fertilizer has been shown to improve plant growth on infertile soils[12,13,24]. This material adds both plant nutrients and organic matter. Sludges are particularly known for adding nitrogen, phosphorus and micro-nutrients to soils. Fertilizer additions of potassium to supplement this material have been reported[4,20,24] and may be required if soils are low in this element.

On newly seeded soils, mulches are beneficial in counteracting excessive or deficient moisture conditions, as well as in providing protection against soil crusting. Mulches retard soil erosion and seedwashing during heavy precipitation and retain moisture during dry periods. Musser and Perkins[21] noted that many seeding failures could be attributed to the absence of a mulch.

Because of the low moisture-holding capacity of gravel soils, mulches are necessary for optimum seedling establishment. Tacked straw, wood fiber mulch and excelsior blanket appear to be the most effective mulch materials in several research studies[1,6,7,12,14,15,17,21,29,30]. Rates of application average about 2 tons/acre for straw and about 1000 to 2000 lb/acre for wood fiber mulch.

Although straw and hay are effective mulching materials, new materials are continually being developed because of the decreasing availability of good mulch hay or straw[9,16]. The types of mulches that have been studied can be found in reviews of these materials and in specific research reports and roadside studies[5,16,20].

The kinds of grasses and legume species recommended for seeding newly constructed sites vary with geographical area. Species adaptation to local climatic conditions is important. Hottenstein[16] notes, in a review on roadside plants, the different types of grasses used throughout the United States. Although similar plant species are sometimes used for roadsides and pastures, seeding rates on roadsides and other low maintenance areas are greater because of the poor quality of seedbeds.

EXPERIMENTAL DESIGN

This study was designed to investigate separately the effects of mulching materials and nutrient sources for the establishment of vegettion on gravel soils in cold regions. On plots testing different mulches, nutrient source and rate were held constant; and on other plots, which tested variable nutrient source rates, a constant mulch was used. Research plots were established in the early growing season of 1976 at two locations: in May at CRREL in Hanover, New Hampshire, and in June at the CRREL Alaskan Projects Office Field Station in Fairbanks, Alaska. Overviews of these sites before treatment and the relatively poor soils studied are shown in Figures 1-4. The plots were assessed during three growing seasons (1976, 1977 and 1978) to document the long-term establishment and growth of the grasses. In May 1977, at the Hanover site only, half of each plot received a supplemental application of nitrogen fertilizer to note its effect on the maintenance of grass growth and soil cover.

A total of 18 treatments were established on plots measuring 10 x 12 ft. They were replicated twice in New Hampshire, resulting in 36 plots, and three times in Alaska, resulting in a total of 54 plots (Table I). Each treatment consisted of a combination of the following factors: a nutrient source (fertilizer or sludge), a mulch (wood fiber mulch and/or peat moss), and a tacking compound (Curasol or the commercial tackifier in Wood Fiber Mulch 2000). Two types of controls were installed—either no treatment or grass seed only.

The sewage sludges applied were obtained from Eielson Air Force Base for the Alaska site and from the Hanover sewage treatment plant for the New Hampshire study. Both sludges used were anaerobically digested primary sludge and contained approximately 33% moisture. They were nearly neutral in pH and contained about 1.22% nitrogen, 0.61% phosphorus and 2.47% potassium. The sludge application rates were 40, 60 and 80 tons/acre.

Fertilizer was broadcast uniformly over the soil surface by hand at each site at rates of 200, 400 and 600 lb/acre. We initially intended to use a 10-10-10 grade fertilizer at both sites. After applying this fertilizer in New Hampshire, we discovered that it was not available in Alaska; therefore, we used a 10-20-20 grade fertilizer in Alaska. Table 2 lists the total amounts of nitrogen, phosphorus and potassium applied at each site by the fertilizer. Similar rates of fertilizer nitrogen, a nutrient that stimulates grass growth, were used at both sites. All of the nutrient treatments received wood fiber mulch at the rate of 2000 lb/acre. In May 1977, at the New Hampshire site, half of each treatment received supplemental fertilizer at the rate of 66 lb/acre of nitrogen from ammonium nitrate fertilizer (34-0-0). This was done to note the effects

Figure 1. New Hampshire site prior to treatment applications.

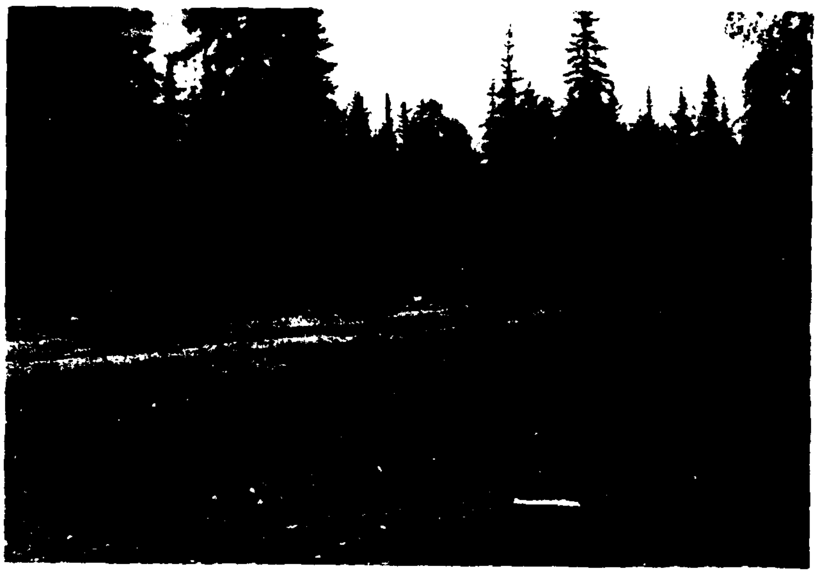

Figure 2. Alaska site prior to treatment applications.

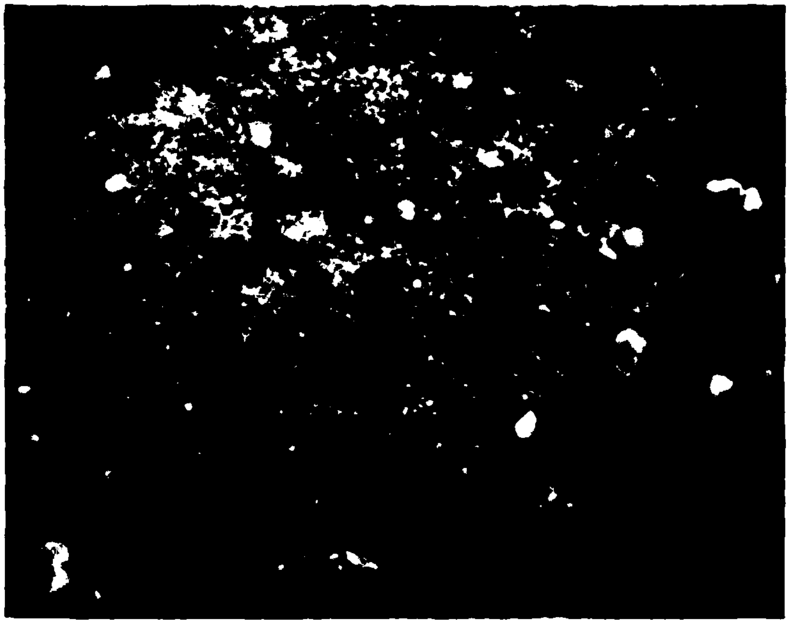

Figure 3. Soil surface at the New Hampshire site.

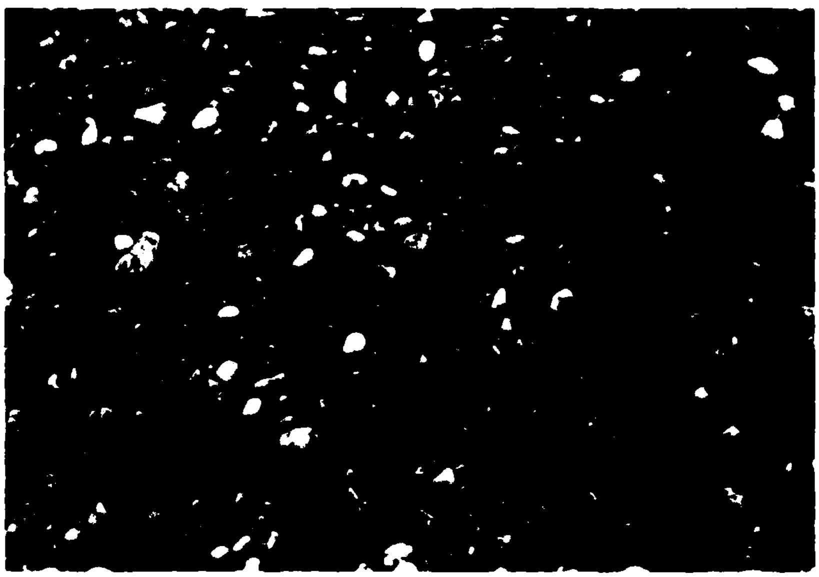

Figure 4. Soil surface at the Alaska site.

Table 1. Plot numbers and treatments.

Treatment	Plots: New Hampshire	Plots: Alaska	Nutrient source*	Mulch
1	1,19	1,19,37	Sludge	WFM 2000†
2	10,28	10,28,46	Fertilizer	WFM 2000
3	3,21	3,21,39	Sludge	WFM + Curasol
4	12,30	12,30,48	Fertilizer	WFM + Curasol
5	4,22	4,22,40	Sludge	Peat moss
6	13,31	13,31,49	Fertilizer	Peat moss
7	5,23	6,24,42	Sludge	Peat moss + WFM
8	14,32	14,32,50	Fertilizer	Peat moss + WFM
9	6,24	7,25,43	Sludge	–
10	15,33	16,34,52	Fertilzer	–
11	2,20	2,20,38	Sludge	WFM
12	11,29	11,29,47	Fertilizer	WFM
13	8,26	8,26,44	Sludge (60 tons/acre)	WFM
14	17,35	17,35,53	Fertilizer (200 lb/acre)	WFM
15	9,27	9,27,45	Sludge (80 tons/acre)	WFM
16	18,36	18,36,54	Fertilizer (600 lb/acre)	WFM
17	7,25	15,33,51	Control	–
18	16,34	5,23,41	Control**	–

*Where not specified, application rates were sludge 40 tons/acre and fertilizer 400 lb/acre

†WFM = Wood Fiber Mulch

**Not seeded

Table 2. Amounts of nutrients applied by commercial fertilizer to each site.

Application rate (lb/acre)	Nutrients applied (lb/acre): N	P	K
Alaska site: 10-20-20 fertilizer			
200	20	17	33
400	40	34	66
600	60	52	100
New Hampshire site: 10-10-10 fertilizer			
200	20	9	17
400	40	17	33
600	60	26	50

of refertilization on the maintenance of grass growth and plant soil cover

The mulching materials used in this study were wood fiber mulch (WFM), peat moss (PM), Wood Fiber Mulch 2000 (WFM 2000) and Curasol. They were applied separately or in combination so that their relative effectivenesses could be determined.

Tacking compounds were combined with two of the mulch treatments to help reduce wind erosion of the mulch and/or soil. Curasol, a white viscous liquid with a pH of 4.5 to 5.0, was applied with the wood fiber mulch at the rate of 30 gal./acre and a dilution of 50:1, determined by field testing. The selected dilution rate fell almost at the midpoint of the manufacturer's recommended range of 4:1 to 90:1. The other tacking treatment used was Wood Fiber Mulch 2000. In this product, a tacking compound is incorporated into the wood fiber mulch when it is manufactured. The tacking chemical is later activated upon mixing with water.

The six resulting mulch treatments were: 1) wood fiber mulch (WFM), 2) wood fiber mulch plus Curasol (WFM + C), 3) Wood Fiber Mulch 2000 (WFM 2000), 4) peat moss and wood fiber mulch (PM + WFM), 5) peat moss (PM), and 6) no mulch treatment (CONTROL) (Table 1). All mulches were applied at the rate of 2000 lb/acre and had a constant fertility rate of either 40 tons/acre sludge or 400 lb/acre fertilizer. Figures 5 and 6 show individual plots that received mulch treatments. Figures 7 and 8 show the completed plots.

The seed mixture sown in Fairbanks contained Nugget Kentucky bluegrass (*Poa pratensis* L.), Pennlawn red fescue (*Festuca rubra* L.), and Saratoga smooth bromegrass (*Bromus inermis* L.) (Table 3). In Hanover, reed canarygrass was substituted for smooth bromegrass. This seed mixture was developed so that the sown vegetation would germinate and stabilize soils rapidly and then withstand extreme environmental conditions (low rainfall, low temperatures, and low soil fertility). Nugget Kentucky bluegrass is a species developed in Alaska that can withstand low temperatures. Seed of this species is readily available because of its popularity as a lawn grass in the continental United States. Pennlawn red fescue and reed canarygrass were selected for their tolerance to low fertility and droughty soils. The final species, Saratoga smooth bromegrass, was chosen for its rapid germination and its resistance to low temperatures. This mixture was sown uniformly at the rate of 60 lb/acre.

Each site was marked as to its respective plot designs; then the various treatments were applied. The order of application of materials was: 1) nutrient sources, 2) seed mixture, and 3) mulch treatments. Agricultural limestone was also applied at 1 ton/acre to all plots—initially at the Alaska site, and after the sludge treatments at the New Hampshire site.

Three main categories of data were collected: 1) Vegetation establishment and growth were assessed by visually estimating the percentage of vegetative cover and the overall quality of the plants during the study. 2) Soil samples were taken before and about one year after treatment applications to note changes in soil fertility. The soils were sampled (at the 0-4 in. depth in Hanover and the 0-4 and 4-8 in. depths in Fairbanks) to determine any movement of nutrients within these coarse-textured soils. The samples were analyzed for pH, phosphorus and potassium following the procedures outlined by Liegel and Schulte[19]. The analyses of the soils prior to treatment are shown in Table 4. Plant yields were measured in Hanover during the third year of study to note biomass production which resulted from the various nutrient sources and rates. Grasses from the whole plot were clipped with a sickle bar mower. Grab samples

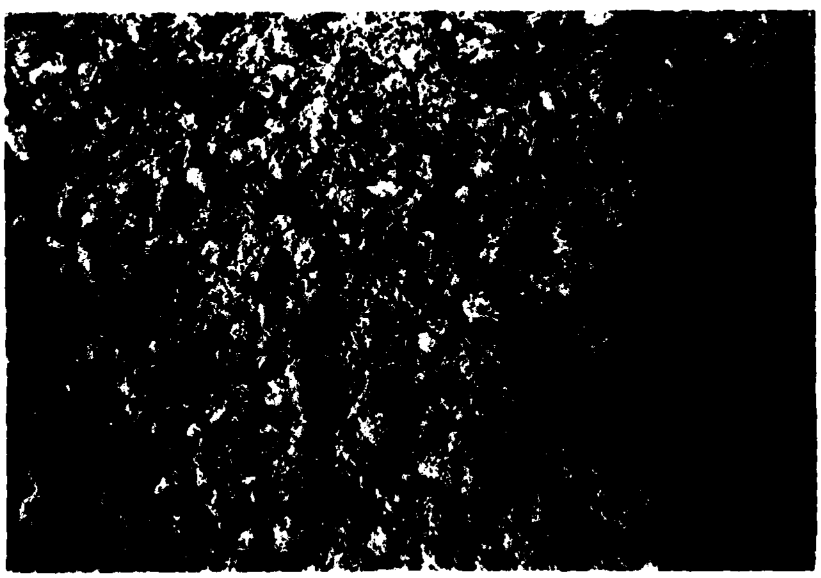

Figure 5. Soil surface of plot that received wood fiber mulch.

Figure 6. Soil surface of plot that received Wood Fiber Mulch 2000.

Figure 7. New Hampshire plots.

Figure 8. Alaska plots.

Table 3. Grass seed mixtures and amounts applied to the test sites.

Species	Amount (%)	Application rate (lb/acre)
Nugget Kentucky bluegrass	40	24
Pennlawn red fescue	40	24
Saratoga smooth bromegrass or Reed canarygrass	20	12
Total	100	60

Table 4. Initial chemical and physical analyses of soils.

Site	Soil depth (in.)	Organic matter (tons/acre)	pH	P (lb/acre)	K (lb/acre)	Sand (%)	Silt (%)	Clay (%)
Fairbanks	0-4	15	7.0	58	65	88	10	2
Fairbanks	4-8	13	6.8	49	60	88	10	2
Hanover	0-4	5	6.6	73	50	80	18	2

were then dried at 158°F for 48 hours to constant weight to obtain yields on a dry weight basis

CLIMATE

The test sites are both in cold climates although Fairbanks has a much lower mean annual temperature than Hanover. Fairbanks, located in the interior basin of Central Alaska, has a continental climate[22]. Precipitation normally follows a regular subarctic pattern and totals about 11.2 in./yr. Growing season precipitation normally builds up through the summer months to a maximum average of 2.19 in. in August (Table 5). The normal mean annual temperature is 25.7°F. The highest and lowest temperatures recorded are -65° and 99°F.

The climate at the Hanover site is Woodland of the Cool-Temperate Zone[18]. Normal yearly precipitation is 37.3 in. with the normal monthly maximum of 4.18 in. occurring in July (Table 6)[28]. The normal mean annual temperature is 44.8°F. The highest and lowest recorded temperatures are 101°F and -40°F[22].

In summary, both sites experience a great range in temperatures with Fairbanks receiving only about one third as much precipitation as Hanover. The low temperatures experienced at both sites during the winter months indicate a greater degree of frost action and freezing of soils than in areas in warmer climates. These environmental conditions usually increase the susceptibility of plants to winter killing.

Growing season conditions during the three study years at both sites were variable (Tables 5 and 6)[22,27]. In 1976, Hanover weather was slightly cooler and much wetter than normal, while Fairbanks weather was warm and dry, especially in August. Precipitation in Hanover fluctuated throughout the 1977 season: dry in May, wet in June, very dry in July, slightly dry in August, and wet in September. Temperatures were close to normal. Fairbanks also experienced variable moisture conditions in 1977 between May and September, changing from wet to dry to wet, with August being the driest month. It was generally warmer then normal, especially in August. The final year in Hanover again had fluctuating precipitation (although less extreme) with temperatures averaging slightly less than normal. May and July were dry months and June and August were wet. Fairbanks had less extreme variability in precipitation, with May and June

Table 5. Average temperature and precipitation in Fairbanks.[22]

	Temperature (°F)				*Precipitation (in.)*			
Month	*Normal mean*	*1976*	*1977*	*1978*	*Normal total*	*1976*	*1977*	*1978*
Jan	-11.9	-11.5	-9.8	-0.1	0.60	0.22	0.31	0.39
Feb	-2.5	-13.7	-8.6	-3.9	0.53	0.01	0.81	0.19
Mar	9.5	12.1	4.6	14.0	0.48	0.55	0.26	0.09
Apr	28.9	36.0	27.8	34.8	0.33	0.08	0.36	0.16
May	47.3	47.8	48.7	50.2	0.65	0.94	1.63	0.44
Jun	59.0	59.6	59.4	54.6	1.42	1.08	3.01	1.71
Jul	60.7	61.8	62.8	63.5	1.90	1.60	1.58	1.19
Aug	55.4	59.2	62.6	—	2.19	0.69	0.41	—
Sept	44.4	45.4	45.6	—	1.08	1.05	2.51	—
Oct	25.2	23.9	25.6	—	0.73	0.89	1.11	—
Nov	2.8	15.9	-7.6	—	0.66	0.13	0.19	—
Dec	-10.4	-3.9	-14.9	—	0.65	0.08	0.80	—
Average	25.7			Total	11.22			

Table 6. Average temperature and precipitation in Hanover.

Month	Temperature (°F) Normal mean	1976	1977	1978	Precipitation (in.) Normal total	1976	1977	1978
Jan	19.2	10.0	8.8	15.8	2.87	3.09	1.75	4.31
Feb	20.9	26.0	20.0	12.2	2.40	3.42	1.95	0.77
Mar	30.5	32.0	36.2	26.6	2.77	2.34	4.05	1.19
Apr	43.4	47.6	42.7	39.0	3.13	3.03	3.25	2.09
May	55.3	53.0	57.0	58.1	3.30	5.64	1.55	1.69
Jun	64.6	68.0	61.4	62.6	3.30	4.29	5.50	4.09
Jul	69.2	66.0	66.9	68.0	4.18	5.12	0.97	2.24
Aug	67.2	65.0	65.7	66.2	3.07	4.38	1.87	3.83
Sept	59.4	55.9	57.2	—	3.38	3.18	4.20	—
Oct	48.3	43.6	45.1	—	2.82	5.82	5.57	—
Nov	36.5	31.2	38.5	—	3.36	1.58	2.88	—
Dec	22.9	15.9	23.9	—	2.72	1.78	2.68	—
Average	44.8			Total	37.3			

being close to normal and July fairly dry. Temperatures in Fairbanks, between May and July, went from warm to cool to warm.

RESULTS AND DISCUSSION

Nutrient sources

Sewage sludge

In both Hanover and Fairbanks, the various application rates of sewage sludge promoted seedling establishment and increased grass cover on the soil surface over the controls (Fig. 9-11). In Hanover, after the first season no real differences in plant cover relating to application rates were noted, while at Fairbanks the 80-ton/acre application produced the best plant growth (Fig. 12). In Hanover, during the summer of the second growing season (1977), grass ratings were depressed on all sludge plots. This poor grass growth was related to the dry summer. Ratings improved with the onset of cooler, wetter conditions in the fall. In Fairbanks, the second season ratings were higher than those of the first season. In the summer of the third growing season (1978), grass ratings remained high at both sites but were slightly depressed in Fairbanks relative to the previous year. At the end of the study period grass ratings were similar for the three application rates studied at each site.

Commercial fertilizer

All plots treated with commercial fertilizer in Hanover (Fig. 13) had slower grass establishment than those treated with sludge. No real grass response occurred until the end of the second growing season. In Fairbanks, initial grass establishment was quicker, especially at the two higher fertility rates of 400 and 600 lb/acre (Fig. 14). During the second season and at the end of the study, greater differences were noted between application rates. Grass ratings of the individual application rates at both sites were in the following order: 400 > 600 > 200 and 0 lb/acre. In Fairbanks the 200-lb/acre treatment was similar to the control which received only seed.

In general, grass cover on the Hanover plots that received commercial fertilizer was not as great as that on plots that received sewage sludge (Fig. 15). In Fairbanks, initial ratings were greater on the fertilized soils, but only 23 days later the sludge treatments were better (Fig. 16). With the exception of the 2 August 1976 rating in Fairbanks, grass establishment and growth were better in the sludge-treated soil during this three-year study than in those soils treated with commercial fertilizer.

Refertilization

In May 1977, half of each treatment in Hanover received a supplemental application of nitrogen fertilizer. The fertilizer, ammonium

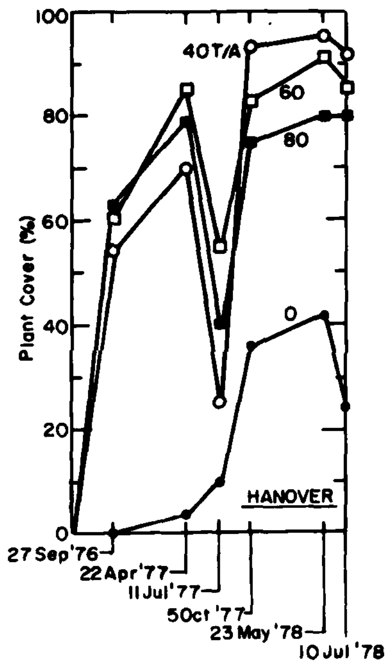

Figure 9. Percentage of grass cover on sludge plots in Hanover.

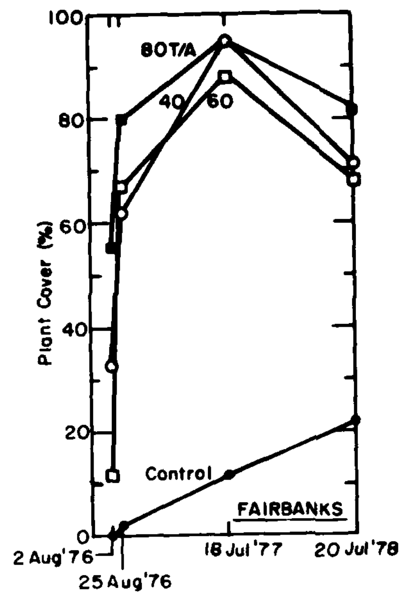

Figure 10. Percentage of grass cover on sludge plots in Fairbanks.

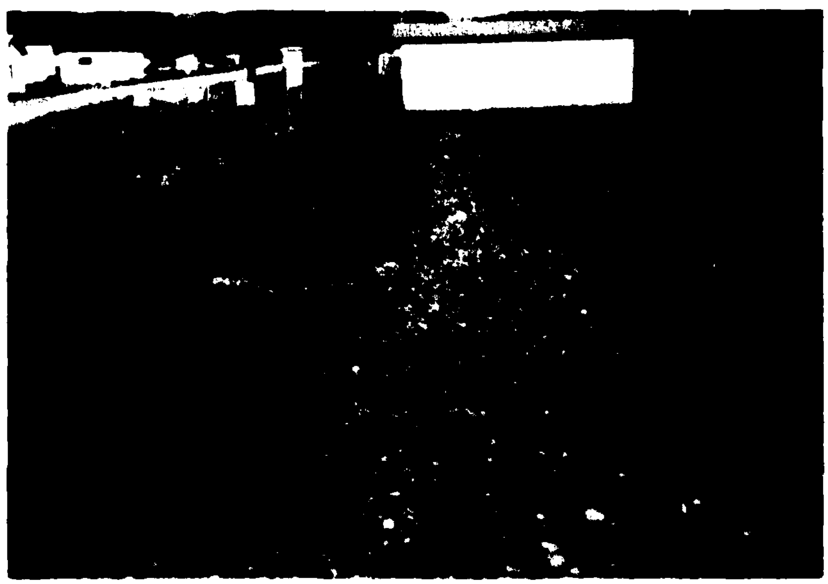

Figure 11. Grasses that received sewage sludge (left) and commercial fertilizer (right) in Hanover.

Figure 12. Plots that received 60 tons/acre (foreground) and 80 tons/acre (background) of sewage sludge in Fairbanks.

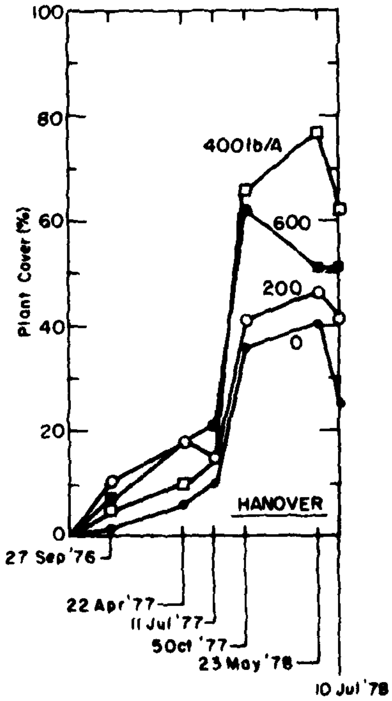

Figure 13. Percentage of grass cover on plots receiving commercial fertilizer in Hanover.

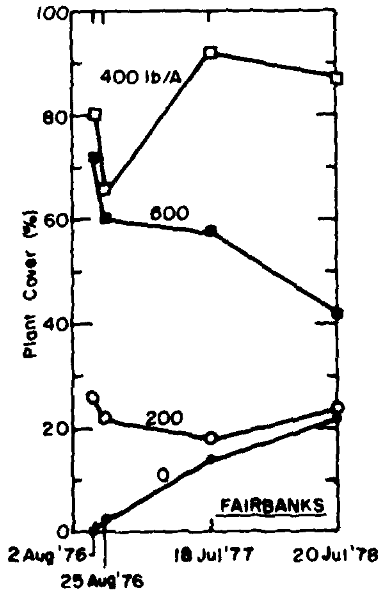

Figure 14. Percentage of grass cover on plots receiving commercial fertilizer in Fairbanks.

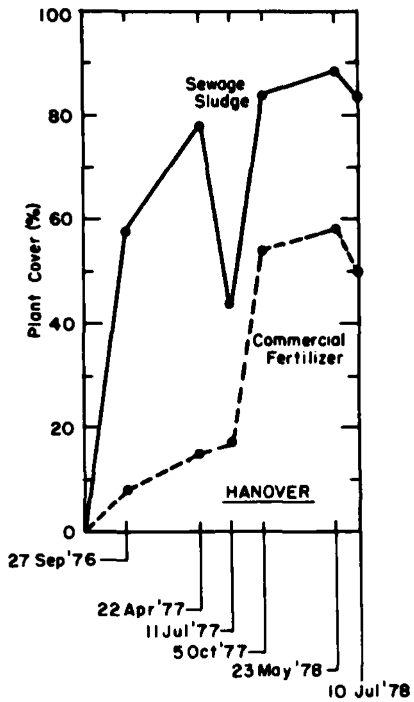

Figure 15. Average percentage of grass cover of sludge vs commercial fertilizer in Hanover.

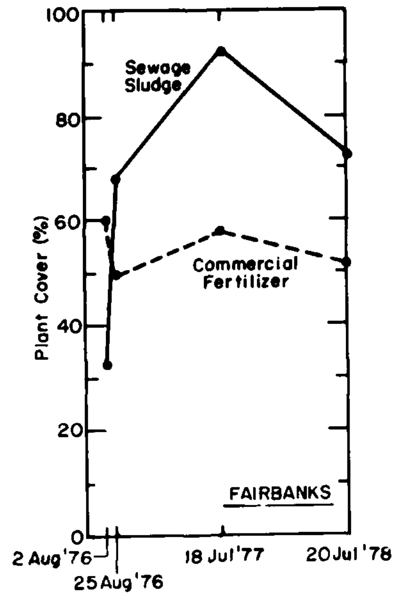

Figure 16. Average percentage of grass cover of sludge vs commercial fertilizer in Fairbanks.

nitrate (34-0-0), was applied at the rate of 200 lb/acre which supplied 66 lb/acre of nitrogen.

As noted in Figures 17-20, grasses receiving supplemental fertilizer grew better for the remainder of the study regardless of the nutrient source used. In the treatments that received sewage sludge at seeding, the supplemental fertilizer helped maintain better grass growth (Fig. 17). This was especially true during the summer of the second growing season when the other treatments had depressed ratings from the summer conditions.

A more beneficial response to refertilization was noted for grasses that initially were treated with commercial fertilizer. This refertilization increased grass ratings to over 80%, while grasses that were not subsequently fertilized never received ratings better than 60% soil coverage (Fig. 18).

Plant yields

Plant yields or total biomass production of grasses were measured in Hanover in August 1978 or during the third growing season (Table 7). No large differences in yields between application rates of either commercial fertilizer or sewage sludge were noted at this time. Greater differences were noted in grasses receiving supplemental applications of commercial fertilizer than in those that did not. Refertilization increased yields from 39 to 145% for both the initially fertilized and sludged plots. Greater plant weights were noted for grasses that originally received sewage sludge as compared with those that received commercial fertilizer.

No harvesting was done in Fairbanks because of the costs involved in securing equipment and transferring personnel to the site.

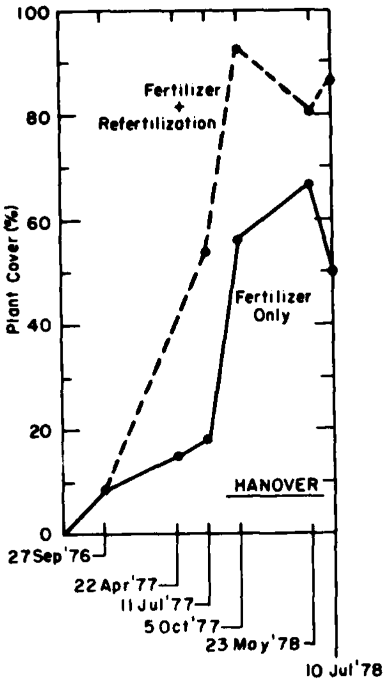

Figure 17. Percentage of grass cover on sludge plots with and without refertilization in Hanover.

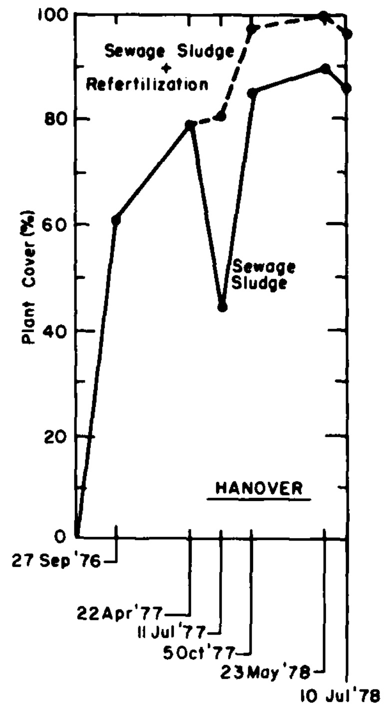

Figure 18. Percentage of grass cover on fertilized plots with and without refertilization in Hanover.

Figure 19. The effects of refertilization on grass growth on plots that initially received sewage sludge. Grasses at left received 66 lb/acre of nitrogen fertilizer.

Figure 20. The effects of refertilization on grass growth on plots that initially received fertilizer. Grasses at left received 66 lb/acre of nitrogen fertilizer.

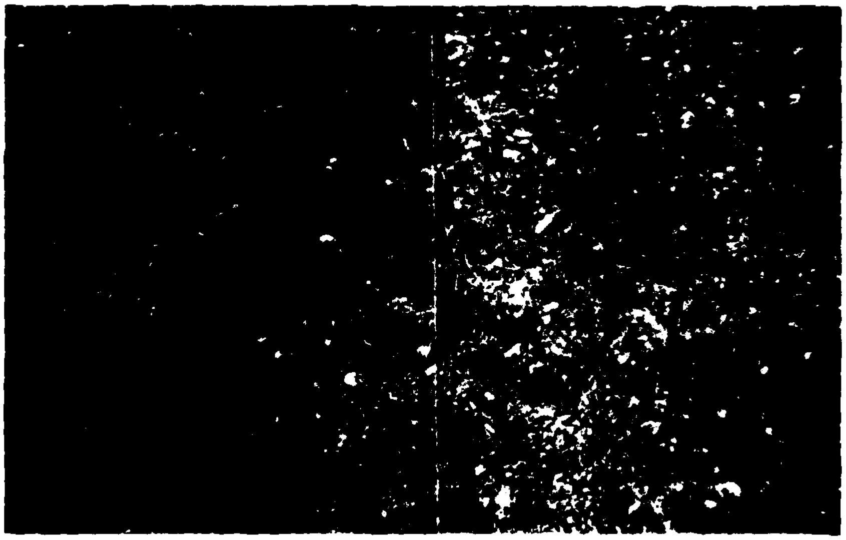

Figure 21. Increased soil cover by grasses (on left) receiving supplemental fertilizer.

Table 7. Total biomass production (yields) of grasses in Hanover during harvesting in August 1978.

Treatment	Without refertilization (lb/acre)	With refertilization (lb/acre)	Difference (%)
	Sewage sludge (tons/acre)		
0	735	1078	48
40	2181	4355	100
60	2581	5146	99
80	2373	3548	50
	Fertilizer (lb/acre)		
0	735	1087	48
200	1183	2173	84
400	1206	1894	57
600	1342	3284	145

Mulches

The effectiveness of a mulch is most significant during the first growing season since its purpose is to promote seed germination and seedling establishment by maintaining a more nearly optimum soil temperature and moisture content. Therefore, grass ratings were taken at both sites near the end of the initial growing season to compare the effectiveness of the various mulch treatments with either sewage sludge or commercial fertilizer as a nutrient source (Tables 8 and 9; Fig. 22). In all cases, the mulched plots did much better than the unmulched controls.

Sludge

At the end of the initial season at both sites, ratings for WFM 2000 and WFM were highest among the mulch plots treated with sludge (Fig. 22). These were followed by WFM plus Curasol and the peat moss combinations which had somewhat similar ratings. Sewage sludge used alone had ratings slightly less than the peat moss group. Tables 8 and 9 also list ratings for the second and third growing seasons. In general, the various mulch effectiveness ratings stayed in the same relative order throughout the study.

Fertilizer

During the first season in Hanover mulch plots treated with commercial fertilizer did poorly (Fig. 22). The same plots did quite well in Fairbanks, however, and on the whole had higher grass ratings than the sludge plots. Relative ranking of the mulches was the same as for the sludge plots, except that WFM had ratings closer to the peat moss group than to WFM 2000. The fertilized mulches, in general, also kept the same ranking throughout the remainder of the study (Tables 8 and 9).

Soil fertility

Soil samples taken over time and analyzed for chemical content can be compared to note improvements in soil fertility and movement of plant nutrients in the soil due to the applications of sewage sludge or fertilizers. For this purpose, soils at both sites were sampled at the 0-3- and 3-6-in. depths in Hanover and at the 0-4- and 4-8-in. depths in Fairbanks prior to treatment establishment and again about one year later (in Hanover in May 1977 and in Fairbanks in July 1977). The samples were analyzed for pH, phosphorus and potassium (Tables 10 and 11). It should be noted that desirable soil pH is near neutrality and adequate levels of phosphorus and potassium are usually stated as being about 50 and 150 lb/acre, respectively[19]. At both sites, then, initial soil content of phosphorus was adequate, but the content of potassium was low. The pH level was at neutrality in Fairbanks and slightly acidic in Hanover.

In the upper soil profile at both sites (0-3 in. in Hanover and 0-4 in. in Fairbanks), soil levels of phosphorus and potassium were increased relative to the initial levels (controls) because of the application of sewage sludge or fertilizer (Tables 10 and 11). The pH was also increased, primarily due to the 1 ton/acre lime application at seeding.

Soil contents in the lower profile at both sites (3-6 in. in Hanover and 4-8 in. in Fairbanks) were also increased relative to the initial samples (Tables 10 and 11). These high values of soil pH, phosphorus and potassium at the lower depth indicate movement or leaching of these elements through the coarse soil profile and away from plant roots.

Cost analysis

A cost analysis was prepared to determine the cost effectiveness of the installation for each treatment on a per-acre basis. Values used in the analysis for the materials and labor costs were chosen from the national averages listed in

Table 8. Percentage of grass cover in Hanover for the various mulch treatments.

Treatment*	1976 27 Sept	1977 22 Apr	1977 11 Jul	1977 5 Oct	1978 23 May	1978 10 Jul
SS + WFM 2000	63	80	55	100	100	100
SS + WFM	55	70	35	93	95	90
SS + WFM + Cu	40	70	30	88	80	85
SS + PM	40	65	30	75	70	70
SS + PM + WFM	35	65	30	73	65	70
SS	28	50	25	73	63	80
F + WFM 2000	8	8	15	80	70	55
F + WFM	5	10	15	65	75	60
F + WFM + Cu	10	13	20	60	48	50
F + PM	8	8	20	65	40	45
F + PM + WFM	8	8	10	40	33	25
F	5	10	10	20	35	25

*SS = sewage sludge; F = fertilizer; WFM = wood fiber mulch; PM = peat moss; and Cu = Curasol.

Table 9. Percentage of grass cover in Fairbanks for the various mulch treatments.

Treatment	Grass cover (%) 2 Aug 76	25 Aug 76	18 Jul 77	20 Jul 78
SS + WFM 2000	55	88	92	75
SS + WFM	33	62	95	70
SS + Cu + WFM	45	45	88	57
SS + PM	17	30	88	52
SS + PM + WFM	25	38	88	82
SS	2	23	80	60
F + WFM 2000	80	80	93	87
F + WFM	80	65	92	87
F + Cu + WFM	72	57	65	40
F + PM	51	53	58	40
F + PM + WFM	50	53	42	47
F	22	35	33	27

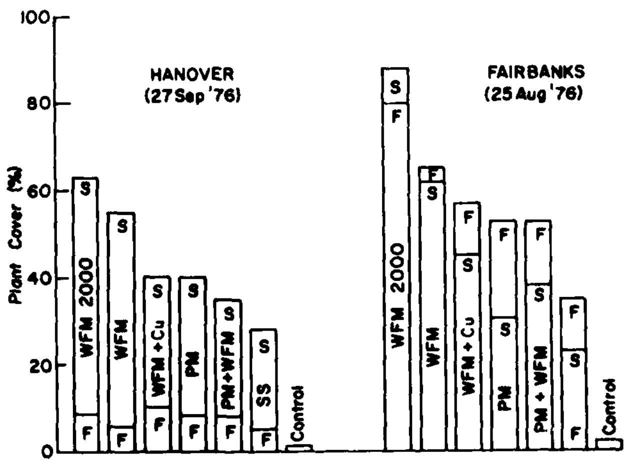

Figure 22. First season grass cover percentage on various mulch treatments in Hanover and Fairbanks.

Table 10. The effects of the various application rates of fertilizers and sewage sludge on soil fertility in Hanover approximately 1 year after initial application of nutrients.

Nutrient	pH		P (lb/acre)		K (lb/acre)	
	0-3*	3-6	0-3	3-6	0-3	3-6
40 tons/acre SS	7.8	7.7	81	100	60	65
60 tons/acre SS	7.4	7.3	73	98	60	60
80 tons/acre SS	7.7	7.2	85	86	60	75
200 lb/acre F	7.6	7.5	64	83	60	70
400 lb/acre F	7.2	7.3	105	100	60	70
600 lb/acre F	7.4	7.0	113	108	70	90
Control (not treated)	6.6	6.6	73	73	50	50

*Sampling depth in inches

Table 11. The effects of the various application rates of fertilizers and sewage sludge on soil fertility in Fairbanks approximately 1 year after initial application of nutrients.

Nutrient	pH		P (lb/acre)		K (lb/acre)	
	0-4*	4-8	0-4	4-8	0-4	4-8
40 tons/acre SS	7.1	7.1	105	66	87	83
60 tons/acre SS	7.3	7.6	207	102	92	95
80 tons/acre SS	7.3	7.3	223	105	100	87
200 lb/acre F	7.7	7.7	60	60	98	92
400 lb/acre F	7.1	6.3	55	36	107	88
600 lb/acre F	7.7	7.6	94	83	112	120
Control (not treated)	7.0	6.8	58	49	65	60

*Sampling depth in inches

Table 12. Treatment cost breakdown.

Treatment no.*	Treatment	Cost data line reference†	Bare cost ($/acre) Mat	Labor	Total	Total W/O&P
17	G	2.8 45 100 (m)	376	581	957	1230
14	G F (200 lb/acre) M	2.8 45 110 (m)	866	581	1447	1765
10	G F	2.8 45 100	871	581	1452	1770
2						
6	G F M	2.8 45 110	1113	581	1694	2035
12						
4	G F M Cu	2.8 45 110 (m)	1202	581	1783	2135
16	G F (600 lb/acre) M	2.8 45 110 (m)	1360	581	1941	2310
9	G	2.8 45 100 (m)	376	581	957	1230
	SS (40 tons/acre)	2.8 25 10 (m)	0	1132	1132	1585
			376	1713	2089	2815
1	G M	2.8 45 110 (m)	618	581	1199	1495
5	SS (40 tons/acre)	2.8 25 10 (m)	0	1132	1132	1585
11			618	1713	2331	3080
8	M	2.8 45 110 (m)	242	581	823	1080
	G F M	2.8 25 110	1113	581	1694	2035
			1355	1162	2517	3115
3	G M Cu	2.8 45 110 (m)	707	581	1288	1590
	SS (40 tons/acre)	2.8 25 10 (m)	0	1132	1132	1585
			707	1713	2420	3175
13	G M	2.8 45 110 (m)	618	581	1199	1493
	SS (60 tons/acre)	2.8 25 10 (m)	0	1698	1698	2377
			618	2279	2897	3870
7	M	2.8 45 110 (m)	242	581	823	1080
	G M	2.8 45 110 (m)	618	581	1199	1495
	SS (40 tons/acre)	2.8 25 10 (m)	0	1132	1132	1585
			860	2294	3154	4160
15	G M	2.8 45 110 (m)	618	581	1199	1495
	SS (80 tons/acre)	2.8 25 10 (m)	0	2264	2264	3170
			618	2845	3463	4665

*See Table 1 for complete description of treatments

†Line reference from *Building Construction Cost Data*.[16]

G = Grass, F = Fertilizer (400 lb/acre), M = Mulch, Cu = Curasol

Table 13. Treatment cost totals in order of increasing expense.

Treatment no.*	Treatment				Bare cost ($/acre)			Total**
		Nutrient						
	Grass	Type	Amt/acre	Mulch/tack	Mat†	Labor†	Total	W/O&P
18	—	—	—	—	—	—	—	—
17	G	—	—	—	376	581	957	1230
14	G	F	200 lb	WFM	866	581	1447	1765
10	G	F	400 lb	—	871	581	1452	1770
2	G	F	400 lb	WFM 2000	1113	581	1694	2035
12	G	F	400 lb	WFM	1113	581	1694	2035
6	G	F	400 lb	PM	1113	581	1694	2035
4	G	F	400 lb	WFM + Cu	1202	581	1783	2135
16	G	F	600 lb	WFM	1360	581	1941	2310
9	G	SS	40 tons	—	376	1713	2089	2815
1	G	SS	40 tons	WFM 2000	618	1713	2331	3080
11	G	SS	40 tons	WFM	618	1713	2331	3080
5	G	SS	40 tons	PM	618	1713	2331	3080
8	G	F	400 lb	PM + WFM	1355	1162	2517	3115
3	G	SS	40 tons	WFM + Cu	707	1713	2420	3175
13	G	SS	60 tons	WFM	618	2279	2897	3870
7	G	SS	40 tons	PM + WFM	860	2294	3154	4160
15	G	SS	80 tons	WFM	618	2845	3463	4665

*See Table 1 for complete description of treatments

†Mat = materials costs, Labor = labor + installation cost

**Total with overhead and profit includes a materials profit of 10% of the materials bare cost and an overhead calculated at 40% of the labor bare cost

G = Grass, F = Fertilizer, SS = Sludge, WFM = Wood fiber mulch, WFM 2000 = Wood fiber mulch 2000, PM = Peat moss, Cu = Curasol

Building Construction Cost Data[16], a reference to aid contractors in anticipating their construction expenses. New Hampshire and Alaska have cost ranges of about 91% and 137%, respectively, of the national average. These cost indices were not included, however, because they change only the cost values and not the relative ranking of treatments.

Calculation of a treatment installation cost basically involves the addition of all expenses for materials and labor used. This initial cost breakdown is shown in Table 12. Bare costs are listed separately from the total cost, which includes a materials profit of 10% of the materials bare cost and an overhead calculated at 40% of the labor bare cost. Also listed in Table 12 are references to the line number in *Cost Data* from which the cost values were taken. Modification of the values given in *Cost Data* was sometimes necessary (indicated by an "(m)" next to the line reference) and usually consisted of an addition to or subtraction from the materials cost depending on the contents of the treatment.

Applications of seed, commercial fertilizer and mulch were calculated on the basis that hydromulching techniques ($581/acre) would be used for all. Seed materials cost was estimated at $376/acre (based on $1.75/lb and 215 lb/acre as given in *Cost Data*.) The fertilizer materials cost was estimated at $1.25/lb and was varied directly with the rate of application listed for each treatment. The same estimated materials cost was used for all three mulches ($0.12/lb or $242/acre). For treatments that included both peat moss and wood fiber mulch, the hydromulching installation cost was doubled (to $1162/acre) because the mulches would have to be spread in two stages to avoid overloading the equipment.

Sludge application cost was computed as being equivalent to stockpiling and spreading of topsoil. The line reference gives the cost for rough spreading. Modification in this case involved the addition of $34/ 20 tons for hauling and dumping. No materials cost was included for the sludge. The application cost for sludge was also varied with the rate of application.

Treatment total costs per acre, including overhead and profit, range from $1230 for grass seed only to $4665 for grass, wood fiber mulch, and a high rate (80 tons/acre) of sewage sludge (Table 13). In general, the treatments including fertilizer are less expensive ($1765-3115) than those with sludge ($2815-4665). The high cost of sludge, however, is highly dependent on transportation and could be reduced considerably with a nearby source. Increasing the rate of fertilizer or sludge raises the cost, as expected. Adding factors to the basic treatment of grass plus a nutrient source also raises the cost increasingly in the following order: 1) mulch, 2) mulch plus Curasol, and 3) double mulch.

Cost effectiveness of the treatments can be stated only in general terms. Sludge treatments, which were more expensive than the fertilizer treatments by about $1050, promoted significantly better grass establishment. The added expense of higher sludge rates, however, did not greatly improve grass cover. If sludge is not available, though, fertilizer may be cost effective if supplemented with nitrogen in subsequent growing seasons. Among the various mulches, WFM 2000 and WFM were the most cost effective in grass establishment and were among the least expensive mulches.

SUMMARY AND CONCLUSIONS

The objectives of this study were to investigate the applicability and cost effectiveness of various nutrient sources and mulch materials for revegetation of gravel soil test sites in cold regions. Test sites located in Hanover, New Hampshire, and Fairbanks, Alaska, were studied for three growing seasons. Three rates each of sewage sludge and commercial fertilizer were used. Mulching materials studied were wood fiber mulch with various types of tackifiers, peat moss and sewage sludge. Desirable treatments improved establishment and/or maintenance of grasses on these poorly productive gravel soils at a relatively low cost.

In many respects the use of sewage sludge at both sites was superior to the use of fertilizer at the application rates studied. This was especially evident in Hanover, where grasses receiving sludge showed superior establishment rates. In Fairbanks, which has a cooler climate than Hanover, a faster establishment rate was noted on plots treated with commercial fertilizer. Only 20 days after the initial rating, however, the grasses that received sludge treatments had an establishment rate either similar to or better than that of the fertilized grasses. At both sites the growth of grasses that received sludge treatments continued to be superior to the growth of grasses that were fertilized.

The greater sludge and fertilizer application rates in Fairbanks gave slightly faster grass establishment than the lower rates, while in Hanover all sludge rates were similar and all did well. All fertilizer treatments did poorly in Hanover. During the second season at each site, little evidence of differences in plant growth was noted among rates of either sludge or fertilizer applications, with the exception of the 400-lb/acre fertilizer treatment in Fairbanks.

Soil coverage by the grasses continued to improve at both sites into the second growing season. Three years of data from two geographical locations show that mulches are highly beneficial to grass establishment. All plots with mulch treatments performed better than the unmulched control plots, which had poor grass growth and vegetation cover. At both sites, Wood Fiber Mulch 2000 and wood fiber mulch were the best performers. Peat moss and sewage sludge applied either alone or in combination with WFM did not perform as well.

Supplemental applications of nitrogen fertilizer in Hanover early in the second growing season proved highly beneficial. The extra fertlizer increased grass growth on plots that received sludge and especially on those that initially received fertilizer.

During the summer of the second season in Hanover, grass coverage on the soil surface was less than during the previous spring. This lower coverage was most likely the result of heat stress and drought. The supplemental fertilizer application, however, prevented this summer stress period, producing much healthier plants, and increased soil cover that shaded the soil surface. Therefore, mulches were found to be important in providing a more nearly optimum seedling environment for grass establishment during the first season, while supplemental fertilizer applications were noted as being beneficial in maintaining grass growth during subsequent seasons.

Applications of sewage sludge or fertilizer were shown to increase the general fertility of the gravel soil, while applications of lime increased soil pH. In some cases increases in the rates of sludge and fertilizer application led to increased soil fertility.

The additions of sewage sludge, fertilizer, and lime materials were also reflected at lower soil depths, indicating leaching of nutrients through the soil profile. This loss of nutrients through leaching in this coarse-textured gravel soil points out the importance of periodic soil testing. Periodic soil testing would determine which soil nutrients are limiting plant growth and assist in developing proper recommendations to be made to correct soil deficiencies.

A cost analysis was prepared which determined that the sludge treatments, which were found to be a better promoter of grass establishment than the commercial fertilizer, were also more expensive. Sludge was found to increase costs of grass establishment by about $1100/acre. The mulches that performed best were WFM and WFM 2000; they were approximately equal in cost. The cost of sewage sludge is highly dependent on transportation costs. If the sewage sludge had been located near the site, the grass establishment costs listed in this report would have been reduced.

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